DEVELOPMENT OF A 1680-MEGACYCLE POWER OSCILLATOR

FINAL REPORT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA

by
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SECTION 1

INTRODUCTION

The purpose of this program was to develop a 1680-Mc power oscillator with the electrical characteristics of the RCA 7533 oscillator but ruggedized so that it could be used in the telemetering payload of a meteorological sounding rocket. The 7533 is widely used in a balloon-lofted meteorological sonde, but it is not rugged enough to withstand rocket launching and payload ejection. The new oscillator shown in Fig. 1, was given the type number RCA A-15497.

The NASA specification for the oscillator is given in abbreviated form in Table I of Section 2 and is included in its entirety as an appendix to this report.

The oscillator developed meets or exceeds all of the requirements — electrical, mechanical, environmental, life, and reliability — of the specification. It has been designed so that it can be produced at low cost with standard manufacturing facilities. The size and shape of the new oscillator and the voltages and currents it uses are such that it can be used in the meteorological telemetry package without modifying the package in any way.

As required by the contract, RCA delivered to NASA at the end of the program six oscillators that met all specifications.

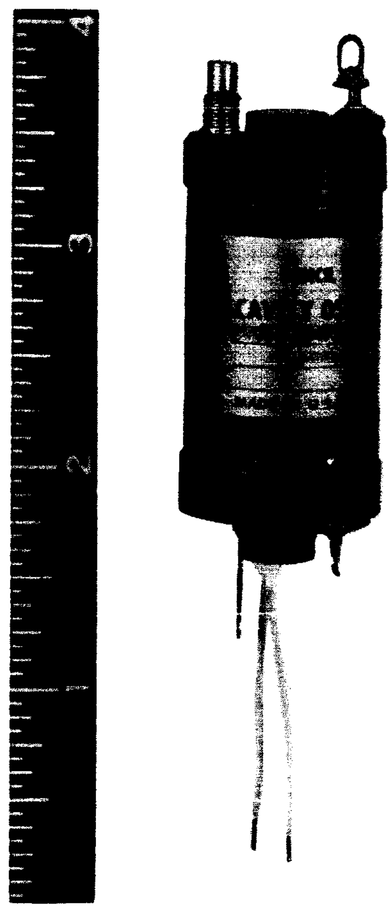

Fig. 1 — RCA A-15497, the 1680-Mc power oscillator developed under the program.

SECTION 2

WORK PERFORMED DURING THE PROGRAM

This section of the report describes the work performed in developing and testing the RCA A-15497 power oscillator.

Table I compares the NASA specifications (and those of the RCA A-15497) with those of the RCA 7533 oscillator for the balloon-lofted weathersonde. The table shows that the major work needed was to ruggedize the 7533. Figure 2 shows an outline drawing and Fig. 3, a simplified cross section of the A-15497.

The oscillator consists of two major components, the pencil triode and a tuned-plate, tuned-grid, coaxial-cavity circuit. Two concurrent tasks were set up, one to ruggedize the triode used in the 7533, the other, to develop the rugged coaxial cavity.

A third task would follow — to test the complete oscillator to the NASA specifications.

I. TASK I — RUGGEDIZING THE PENCIL TRIODE

Two things had to be done to ruggedize the pencil triode. First, it was necessary to discover if any mechanical resonances were present and to make sure that if they were there, they would not be harmful. Such resonances at frequencies within the range of vibration frequencies expected could cause the tube to destroy itself. Second, it was necessary to introduce a small amount of flexibility in the joint between the grid disk of the triode and the cavity shell. Too rigid a joint could cause the tube to break when large external forces were applied.

TABLE I

CHARACTERISTICS OF THE RCA 7533 WEATHERSONDE OSCILLATOR, NASA SPECIFICATION L-4113, AND THE RCA A-15497 DEVELOPED UNDER THE PROGRAM

	RCA 7533	NASA Spec. L-4113	RCA A-15497 Developed Under the Program
ELECTRICAL			
Frequency (Mc)	1680 (Tunable 1660-1700)	1680 ±2 (Fixed)	1680 ±2 (Fixed)
Connector	Friction-fit coax	Selectro, Subminiature	Same
Power output (mw)	575	—	Same
Heater voltage (volts)	5.2-6.6	—	Same
Plate-to-cathode voltage (V)	—	95 with heater voltage 5.2 117 with heater voltage 6.6	Same
Heater current at 6.0 V (amp)	0.160	—	Same
DC plate-to-grid voltage (V)	124	—	Same
DC cathode-to-grid voltage from a 1500-ohm grid resistor (V)	6.75	—	Same
DC cathode current (ma)	31.5	—	Same
DC grid current (ma)	4.5	—	Same

TABLE I (Continued)

	RCA 7533	NASA Spec. L-4113	RCA A-15497 Developed Under the Program
MECHANICAL			
Weight (oz)	0.8	4.0 (max.)	3.0
Length (inches)	1.73	2.2 (max.)	Same
Diameter (inches)	0.865	1.0 (max.)	0.918
ENVIRONMENTAL			
Operating			
Vibration	Not specified	3/8" D. A. displacement, 20-40 cps; 20 g's RMS, 40-2000 cps (Note 1)	Same
Acceleration	Not specified	200 g's 15 sec 3 axes	Same
Shock	Not specified	250 g's 10 milli-seconds, 3 axes (Note 1)	Same
Temperature	-70 to +165°F	-100 to +160°F (Note 2)	Same
Altitude	0 to 100,000 feet	0 to 300,000 feet (Note 2)	Same
LIFE AND RELIABILITY			
Life	5 hours	100 hours (min)	100 hours
Reliability		High as possible considering cost, etc.	Minimum objective: 130 hours 95% confidence

Note 1 The oscillator must survive these environmental conditions and shall not shift frequency more than ±0.75 Mc after exposure to any combination or all of these environmental conditions.

Note 2 The oscillator must meet all specifications during these environmental conditions and total frequency variation shall not be greater than ±3.0 Mc.

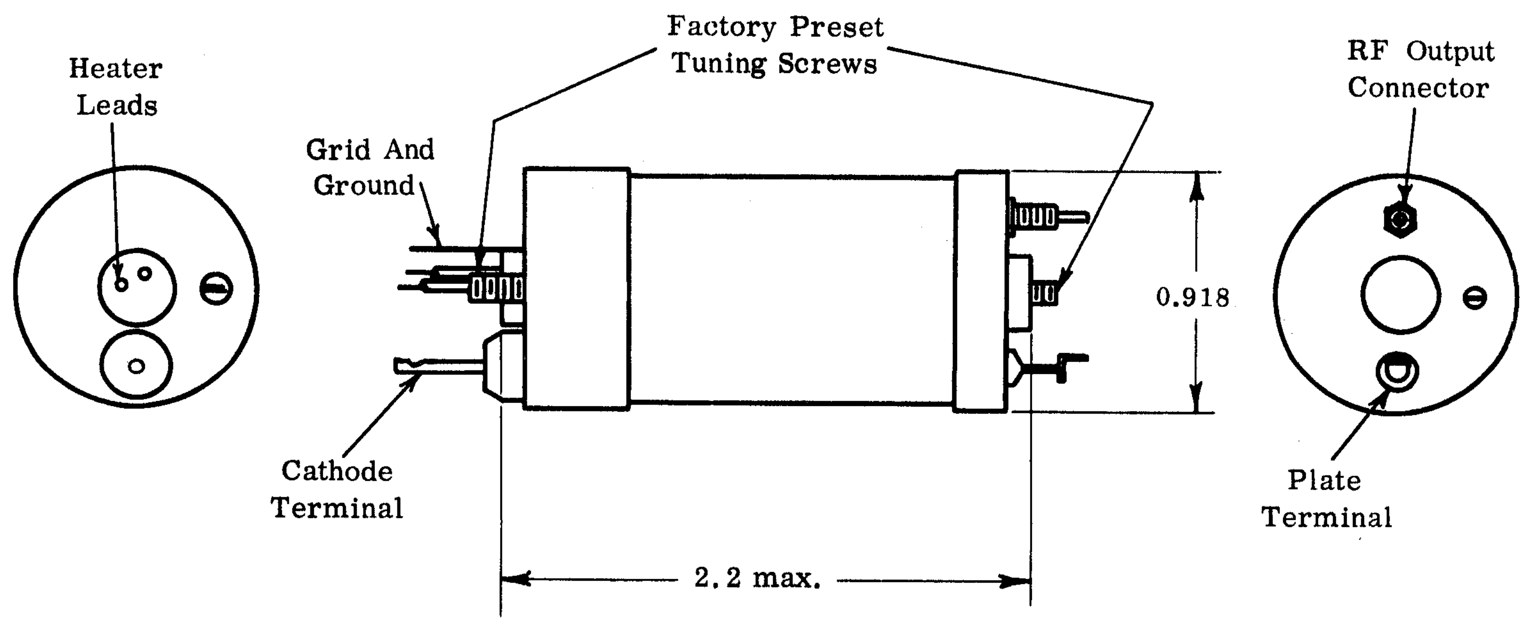

Fig. 2 — RCA A-15497 power oscillator. Outline drawing.

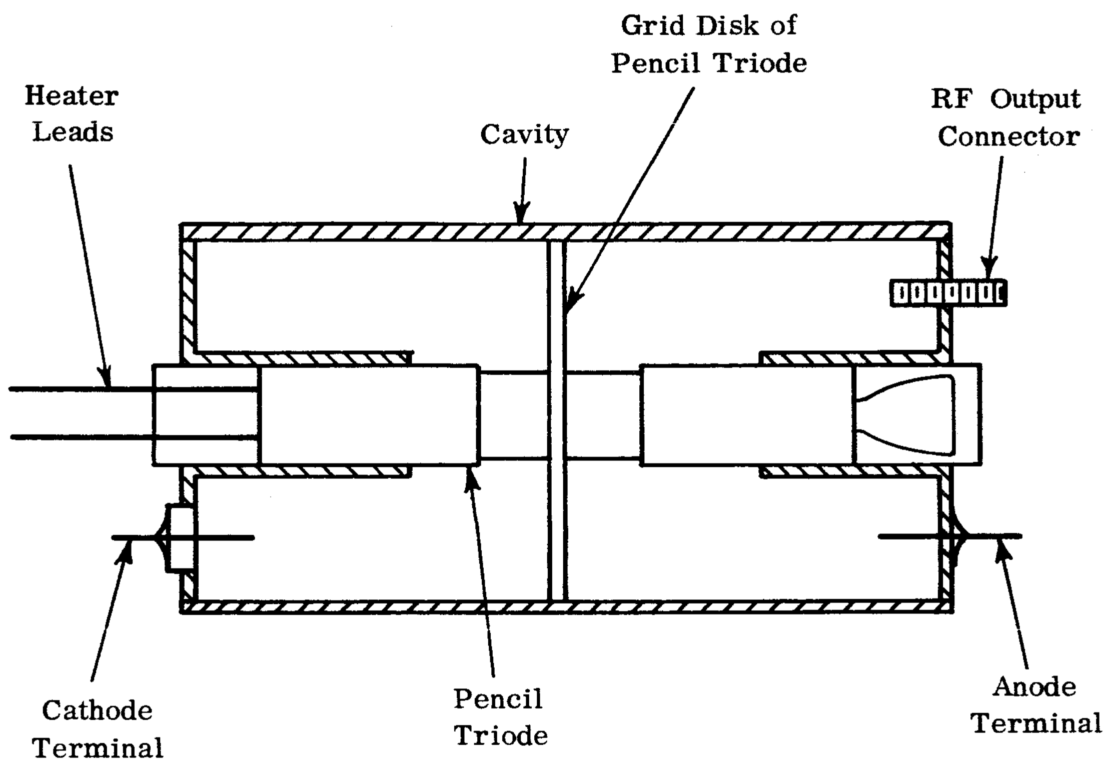

Fig. 3 — RCA A-15497 power oscillator. Simplified cross section.

A. Finding and Shifting the Mechanical Resonances

Previous environmental testing of pencil triodes had shown that noise in the output caused by vibration could be traced to a mechanical resonance of the grid. Previous experience had also shown that the tendency of the cylindrical grid structure to resonate is related to its action in resisting the deformation caused by the application of external forces. It was decided therefore to determine the resonant frequency of the grid of the 7533 so that the resonant frequency of improved structures could be compared with it.

The grid of the pencil tube consists of a group of siderods surrounded by a helix. If the investigation disclosed harmful resonances, the remedy would be to construct the grid from other, stiffer materials.

In all, tubes with three different material arrangements were tested as follows:

	Siderods	Helix
Original 7533	Nickel-clad copper	Silver-clad nickel
First variation	Nickel-clad copper	Tungsten
Second variation and final design of the A-15497	Nickel-plated molybdenum	Silver-clad nickel

Tubes with these three grid designs were rigidly potted into an aluminum block with Emerson and Cuming 3020 Stycast. When this material is soft, it allows for differences in tubes (within dimensional tolerances); when it hardens, it transmits externally applied mechanical forces. The search for resonances was carried out with a force of 5 g's at excitation frequencies up to 5 Kc. Tubes were vibrated in an axis perpendicular to the major tube axis, since this is the most sensitive one. The noise was measured by placing a 10,000-ohm resistor in the plate circuit and measuring the AC voltage developed across it while the tube was being vibrated. The plate voltage was adjusted to provide a plate current of 10 mA.

The tests showed that making the helix of tungsten produced no significant change. The apparent reason for this is that the use of the tungsten did not change the stiffness-to-mass ratio of the structure.

The detailed test results of a typical tube used in the 7533 and a typical tube used in the A-15497 are given in Table II. They show that the grid of the 7533 tube has two resonant frequencies — 2500 and 4000 cps. The grid with the siderods of nickel-plated molybdenum has a resonant frequency of 2850 cps, which is outside the range of vibration frequencies expected. This is the grid that was selected for the A-15497.

TABLE II

VIBRATION-TEST RESULTS OF TYPICAL TUBES USED IN THE RCA 7533 AND A-15497 OSCILLATORS

7533		A-15497	
Vibration Freq.	Noise Output	Vibration Freq.	Noise Output
cps	mV	cps	mV
1325	170	1320	42
2000	480	2390	50
2500	500	2500	280
2950	420	2850	380
4000	800	4000	50

The new grid was manufactured on standard RCA factory facilities and therefore should present no manufacturing problems. The oscillators delivered to NASA under this contract contain tubes utilizing this grid.

B. The New Grid Disk

The second step in ruggedizing the pencil triode consisted of replacing the stiff, one-piece grid disk by a two-piece disk. The center of the new disk, where it joins the glass insulator, is just as thick as the former disk. But at the periphery, there is a thinner, flexible ring which permits the disk to be rigidly fastened to the cavity with no danger of glass breakage.

At no time, during all the construction and testing of the improved pencil triodes in oscillators did any triode fail.

II. TASK II — RUGGEDIZING THE CAVITY CIRCUIT

Two aspects of the work on the cavity circuit were most important. First, to keep the unit very rugged despite the use of low-cost materials and fabrication techniques. Second, to ensure that the unit would operate properly electrically despite the use of a mechanically rugged design.

A. Ruggedizing the Cavity Circuit at Low Cost

The major feature of the RCA 7533 that contributes to its low cost is the sheet-metal cavity shell which is wrapped around the pencil triode and secured by a locking clip. The shell and clip are manufactured as stamped and formed parts, which keeps the manufacturing cost low.

While it was necessary to greatly increase the ruggedness of the cavity circuit, it was also recognized that to keep the cost low, parts should be designed so that they could lend themselves to established volume-production methods. For this reason, the cavity shell was designed so that it can be made of drawn tubing. The two other major subassemblies, the cathode and anode plungers, were designed so that they can be manufactured by stamping. (To minimize frequency changes caused by temperature changes, we selected materials with low temperature coefficients for making the cavity parts.) Machined cavity parts, however, were used in constructing the oscillators delivered to NASA to minimize the investment in tooling costs until our design capability could be fully established.

B. Solving the Electrical-Operation-vs-Ruggedness Problem

The major problem encountered during the development of the oscillator was to design a rugged rf by-pass capacitor and dc blocking arrangement in the plate circuit. The first design utilized a quarter-wave transmission line open at both ends. A metallized cylinder of high-alumina ceramic provided the dc insulation between the triode and the anode plunger. The anode terminal of the triode was soldered to the inner surface of the cylinder, and the center conductor of the cavity was soldered to the outer surface, thus forming a simple but rigid structure. While the device operated quite well, there was considerable rf leakage through and along the plate dc lead.

Experiment showed that a sufficiently strong structure could be built without the use of the ceramic cylinder (which incidentally is quite costly). The design finally adopted consists of a short section of transmission line formed by the anode of the triode covered by a teflon cap (which blocks the dc voltage); this, in turn, is covered by a metal cap. The arrangement is a coaxial capacitor which terminates the line.

The dc plate lead is wound around the anode of the triode and brought out off-center. This design has proven to be quite effective, since there is no rf leakage. Eliminating the ceramic cylinder made it desirable to anchor the tube firmly somewhere in the cavity. This is done by soldering the point of contact between grid disk and cavity; the rf heating coil used for the process makes it a simple job.

The solution of this problem brought with it an additional benefit with regard to the rf output connector. On the early design, it was necessary to use a micro-miniature connector; the type chosen was the Micon 4003. While the connector mounted on the oscillator was satisfactory, both the mating connector and the cable failed during handling and environmental testing. This type of connector, moreover, does not meet the MIL-C-22557 specification. The revised anode design made it possible to use the larger Sealectro Conhex connector which proved entirely satisfactory and which also meets MIL-C-22557.

In making the final assembly of the oscillator, the tube and cavity shell were prepared as the first subassemblies. The cathode and anode subassemblies were added and adjusted to provide proper power output and frequency. The final frequency adjustment was made with the fine tuning screw. This screw was then soldered in place, resulting in a very rigid package.

III. TASK III — TESTING THE OSCILLATOR

Both tubes and oscillators were tested. The tubes were tested before they went into cavities to make sure that only good ones would be put into the cavities. Vibration-test results on a typical tube were given above in Table II.

A. Electrical Tests on Tubes

The results of electrical tests on a representative group of tubes are given below in Table III.

TABLE III

ELECTRICAL-TEST RESULTS ON PENCIL TRIODES FOR THE A-15497 OSCILLATOR

	-Ic μAdc	Ib mAdc	Gm μmhos	μ	CoIb μAdc	Cgp pfd	Cgk pfd	Cpk pfd
1	0.01	30.1	7740	18.1	85	1.21	2.00	0.073
2	0.01	29.3	7430	18.3	7.2	1.27	2.03	0.067
3	0.01	29.0	7470	18.2	88	1.29	2.01	0.068
4	0.01	29.5	7450	18.2	64.0	1.25	2.0	0.070
5	0.01	30.7	7750	17.5	66.0	1.24	1.98	0.071
6	0.01	28.3	7170	18.4	31.0	1.28	1.98	0.071

B. Electrical Tests on the Oscillator

The major portion of the testing, however, was done on the oscillator. Both electrical and environmental tests were performed. Figure 4 shows a block diagram of the set-up used for the electrical tests.

Table IV shows the results of electrical tests on 12 oscillators in nine models. Models A through F were experimental. The remaining six, G1 and 2, H1 and 2, and J1 and 2 met all specifications.

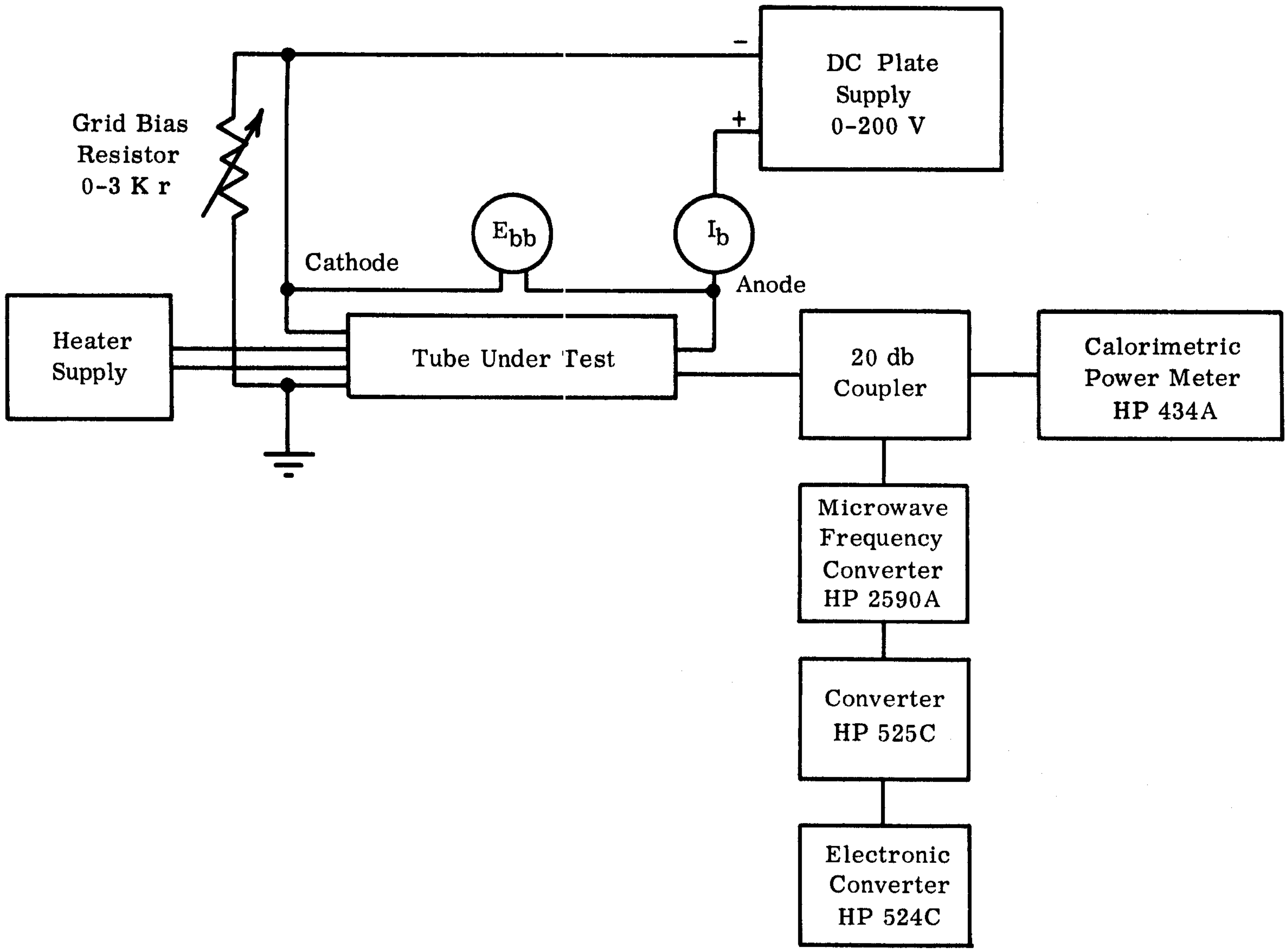

Fig. 4 — Block diagram of the set up used for electrically testing the RCA A-15497 power oscillator.

TABLE IV

ELECTRICAL-TEST RESULTS ON THE A-15497 OSCILLATOR
(Experimental and Prototype Models)

Oscillator Serial No.	E_f V	E_{bb} Vdc	I_b mAdc	I_g mAdc	P_o mW	Freq. mcs	Rg ohms	Remarks
A	5.2	112	30	—	100	1741		First try.
B	5.2	112	30	5.0	200	1680		Adjusted to frequency.
C	5.2	112	30	5.0	240	1740		Optimum performance but device radiates. Inductive pick-up probe.
D	5.2	112	30	5.0	400	1680		Improvement due to use of a capacitive pick-up probe. Still radiating.
E	5.2	112	24.5	5.2	420	1730		Optimum performance with inductive pick-up probe. Still radiating.
F	5.2	95	26.2	—	320	1682		Improvements due to better contacts, but still radiating.
				(Prototype)				
G1	5.2	95	25	2.8	340	1682	1300	
G2	5.2	95	24	4.1	310	1681	1300	
H1	5.2	95	22	3.5	355	1680	1300	
H2	5.2	95	24.5	4.0	430	1683	1300	
J1	5.2	95	21.0	3.05	450	1676.5	1300	Serial Nos. J1 and J2 were also tested for frequency pulling due to change in load. VSWR 1.5 to 1, all phases. Results: Δf (max.) ±2 Mc; ΔP_o (max.) 1.25 db
J2	5.2	95	22.5	3.65	320	1681.6	1300	

As was pointed out above in Paragraph II B, oscillators J1 and J2, which were of the final design, did not radiate.

The electrical-test results on the six oscillators delivered to NASA are given in Table V. Environmental acceptance tests on these oscillators are being conducted by NASA.

C. Environmental Tests on the Oscillator

The environmental tests performed on the oscillator were those prescribed in the NASA specification. The results of these tests (on the prototype oscillators for which Table IV lists electrical-test results) are given in Table VI.

D. Life and Reliability

The specification calls for a minimum operating life of 100 hours and a "reliability as high as possible considering cost and other objectives."

1. Life Tests

Five oscillators (K1, 2 and L1, 2, 3) were given life tests. The tests, run on the five divided into two groups, ran so far beyond the minimum required that they were stopped at the times shown in Table VII.

TABLE VII

LIFE-TEST RESULTS ON A-15497 OSCILLATOR

Oscillator Serial Nos.	Length of Test	Δf (max.) (Mc)	Max. drop in P_o (db)
K1 and K2	420 hours	2.3	1.1
L1, 2, and 3	329 hours	3.0	1.1

TABLE V

ELECTRICAL-TEST RESULTS ON THE SIX OSCILLATORS DELIVERED TO NASA

No.	E_f Volt	E_{bb} Vdc	R_g Ohm	I_b mAdc	I_g mAdc	P_o mW	Freq. mcs
1	5.2	95	1300	21.0	2.3	345	1680.1
	5.9	106	1300	24.5	3.1	510	1679.7
	6.6	117	1300	26.5	3.8	710	1679.2
2	5.2	95	1300	21.0	3.2	330	1681.1
	5.9	106	1300	24.0	4.1	480	1680.3
	6.6	117	1300	27.5	5.0	675	1679.5
3	5.2	95	1300	22.5	3.6	420	1681.8
	5.9	106	1300	25.5	4.4	580	1680.9
	6.6	117	1300	29.0	5.3	780	1680.5
4	5.2	95	1300	21.0	2.6	330	1680.8
	5.9	106	1300	24.0	2.6	495	1679.7
	6.6	117	1300	27.5	4.2	710	1678.9
5	5.2	95	1300	23.0	4.2	400	1680.6
	5.9	106	1300	25.5	5.1	540	1679.7
	6.6	117	1300	29.0	6.0	710	1678.8
6	5.2	95	1300	22.0	2.8	345	1681.8
	5.9	106	1300	25.5	3.6	500	1681.3
	6.6	117	1300	28.5	4.4	700	1680.3

TABLE VI

ENVIRONMENTAL-TEST RESULTS ON THE A-15497 OSCILLATOR

	G1 and G2			H1 and H2			J1 and J2		
		Δf Mc (max.)	ΔPo mw (max.)		Δf Mc (max.)	ΔPo mw (max.)		Δf Mc (max.)	ΔPo mw (max.)
Vibration	Full spec.	0	10	Full spec.	0.4	15	Full spec.	0.4	15
Acceleration	—	—	—	Full spec.	1	65	Full spec.	0.1	30
Shock	200 g's 9 ms	0.2	5	200 g's 9 ms 235 g's 11 ms*	0.2 1.75	0 50	240 g's 9 ms**	0.3	5
Temperature	Full spec.	+3 -1	—	Full spec.	+3.8 -1.7	80	Full spec.	+2.2 -1.0	30
Altitude	125,000 ft. E_{bb} 1.5 x normal	0	0	330,000 ft. E_{bb} 1.5 x normal	0.1	10	—	—	—

* Performed at the Naval Ordnance Laboratory, White Oaks, Md.

** Performed at the Associated Testing Laboratory, Wayne, N. J.

2. Reliability

Considering the minimum life of 100 hours required, the length of the life tests, and the fact that there were no failures, it is evident that the reliability of the A-15497 oscillator is exceptionally high.

APPENDIX A

NASA SPECIFICATION L-4113 FOR 1680 MEGACYCLE OSCILLATOR DEVELOPMENT PROGRAM NOVEMBER 18, 1963

NASA SPECIFICATION L-4113 FOR
1680 MEGACYCLE OSCILLATOR DEVELOPMENT PROGRAM
NOVEMBER 18, 1963

1.0 Scope

This development program will provide a rugged, reliable pencil tube and cavity for meteorological sounding rockets. This tube will be an improved version of the presently employed 7533 and 5794 pencil tubes and cavities. The tube should be a replacement for the 7533 and 5794 having similar operational characteristics, low cost and be available in six (6) months or less for incorporation in meteorolgical sounding rocket payloads.

All characteristics, unless altered in the following sections, shall be equal to or exceed those of the 7533 pencil tube and cavity oscillator.

2.0 Electrical

A. Frequency: Fixed tuned at 1680.0 megacycles ±2.0 megacycles.

B. Connector: The output RF connector shall be a miniature coaxial approved for rocket applications. (See Amendments 1 and 2 below.)

C. See Amendment 1 below.

3.0 Mechanical

A. Weight: Shall be kept to a minimum and shall not exceed 4.0 ounces maximum.

B. Length: Shall be kept to a minimum and shall not exceed 2.0 inches maximum. (See Amendment 1 below.)

C. Diameter: Shall be kept to a minimum and shall not exceed 1.0 inch maximum.

4.0 Nonoperating Environmental (See Amendment 1 below.)

The pencil tube and cavity must survive the following environmental conditions and shall not shift frequency more than ±0.75 megacycle after exposure to any combination or all of the environmental conditions.

A. Vibration: 20 G RMS, 20 to 2000 cps in three axes. (See Amendment 1 below.)

B. Acceleration: 200 G for 1.8 seconds in both directions and three axes. (See Amendment 1 below.)

C. Shock: 250 G for 10 milliseconds in both directions and three axes.

5.0 Operating Environmental

The pencil tube and cavity must meet all specifications during the following environmental conditions and total frequency variation shall not be greater than ±3.0 megacycles.

A. Temperature: -100°F to +160°F

B. Altitude: 0 to 300,000 feet

6.0 Life and Reliability

The pencil tube and cavity must be designed for an operating life of 100 hours or more. The reliability must be as high as possible considering cost and other objectives.

7.0 Quantity

Six pencil tubes and cavities shall be provided to the contracting agency for evaluation at the completion of the contract.

Amendment 1 (8/27/64)

A. Delete paragraph 2.0.B in its entirety and substitute the following:

"2.0.B Connector: Type 4003 Micon Microminiature connector shall be used for the RF output connector."

B. Add the following paragraph 2.0.C

"2.0.C The operating voltage of the tube will conform to MIL-E-1/1311A, October 29, 1963, JAN-7533 Electron Tube which specifies a maximum plate to cathode voltage of 117 volts with a heater voltage of 6.6 volts, and a minimum plate to cathode voltage of 95 volts with a heater voltage of 5.2 volts."

C. Delete paragraph 3.0.B in its entirety and substitute the following:

"3.0.B Length: Shall be kept to a minimum and shall not exceed 2.2 inches maximum."

D. Delete paragraph 4.0 title in its entirety and substitute the following:

"4.0 Operating Environment"

E. Delete paragraphs 4.0.A and 4.0.B in their entirety and substitute the following:

"4.0.A Vibration: 3/8 inch double amplitude displacement, 20-40 cps, 20 G RMS, 40-2000 cps in three (3) axes.

4.0.B Acceleration: 200 G steady state for a minimum of 15 seconds in both directions along each of three (3) axes."

Amendment 2 (11/25/64)

Delete paragraph 2.0.B in its entirety and substitute the following:

"2.0.B Connector: Selectro Corporation, Subminiature type or equivalent in accordance with specification MIL-C-22557, shall be used for the RF output connector."

APPENDIX B

VISITS AND CONFERENCES

VISITS AND CONFERENCES

June 24, 1964	Mr. D. Aldrich of NASA visited RCA, Harrison, to discuss contract progress and test specifications.
September 14, 1964	Messrs. P. Wakefield, F. Keith, and O. Johnk visited NASA, Langley, to discuss contract progress.
November 4, 1964	Messrs. P. Wakefield and O. Johnk of RCA, Harrison, visited NASA, Langley, to discuss contract progress.
November 19, 1964	Mr. B. Kendall of NASA, Langley, visited RCA, Harrison, to discuss contract progress and to observe final testing, prior to shipment.